

## CLAIMS

1. A magnetic head assembly, which has an air bearing surface (ABS), comprising:

5 a spin valve sensor, nonmagnetic first and second read gap layers, a ferromagnetic first shield layer and a ferromagnetic first pole piece layer;

the spin valve sensor being located between the first and second read gap layers and the first and second read gap layers being located between the first shield layer and the first pole piece layer;

10 the spin valve sensor having a pinned layer which has a magnetic moment that is pinned by a pinning layer in a direction perpendicular to the ABS;

a ferromagnetic second pole piece layer and a nonmagnetic write gap layer wherein the second pole piece layer is separated from the first pole piece layer by the write gap layer at the ABS and is connected to the first pole piece layer at a back gap;

15 each of the first shield layer and the first and second pole piece layers having a magnetic easy axis that is directed parallel to the ABS;

20 an insulation stack with a coil layer embedded therein located between the first and second pole piece layers wherein the insulation stack includes at least one baked photoresist insulation layer that has been formed in part by heating at a preselected annealing temperature in the presence of a magnetic field that is directed perpendicular to said ABS;

the insulation stack having been formed subsequent to said sensor and at least the first pole piece layer having not been subjected to annealing in the presence of a magnetic field directed parallel to said ABS before said heating of the layer of the insulation stack; and

25 at least one of the first and second shield layers and the first and second pole piece layers comprising NiFeCo-O-N or NiFeCo-N.

2. A magnetic head assembly as described in claim 1 wherein the second shield layer and the first pole piece layer are a common layer.

3. A magnetic head assembly as described in claim 1 wherein the second shield layer and the first pole piece layer are separate layers and are separated by a nonmagnetic insulative isolation layer.

5           4. A magnetic head assembly as described in claim 1 wherein the second shield layer comprises NiFeCo-N.

          5. A magnetic head assembly as described in claim 1 wherein the second pole piece layer comprises a laminated layer of NiFeCo-O-N films with interlayer  
10 films of Al<sub>2</sub>O<sub>3</sub> or SiO<sub>2</sub>.

          6. A magnetic head assembly as described in claim 5 including:  
a seed layer comprising NiFeCo-O-N;  
the second pole piece layer being directly on the seed layer; and  
15 the seed layer having higher O and N contents than the NiFeCo-O-N of the second pole piece layer.

          7. A magnetic head assembly as described in claim 6 including:  
a bottom layer of SiO<sub>2</sub>; and  
20 the seed layer being located between the bottom layer and the second shield layer.

          8. A magnetic head assembly as described in claim 7 wherein the laminated layer includes four NiFeCo-O-N films that are each substantially 4500 Å thick.  
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          9. A magnetic head assembly as described in claim 8 wherein the second shield layer comprises NiFeCo-N.

10. A magnetic disk drive including a magnetic head assembly having an air bearing surface (ABS), the disk drive comprising:

the magnetic head assembly including:

5 a spin valve sensor, first and second nonmagnetic first and second read gap layers, a ferromagnetic first shield layer and a ferromagnetic first pole piece layer;

the spin valve sensor being located between the first and second read gap layers and the first and second read gap layers being located between the first shield layer and the first pole piece layer;

10 the spin valve sensor having a pinned layer which has a magnetic moment that is pinned by a pinning layer in a direction perpendicular to the ABS;

15 a ferromagnetic second pole piece layer and a write gap layer wherein the second pole piece layer is separated from the first pole piece layer by the write gap layer at the ABS and is connected to the first pole piece layer at a back gap;

each of the first shield layer and the first and second pole piece layers having an easy axis that is directed parallel to the ABS;

20 an insulation stack with a coil layer embedded therein located between the first and second pole piece layers wherein the insulation stack includes at least one baked photoresist insulation layer that has been formed in part by heating at a preselected annealing temperature in the presence of a magnetic field that is directed perpendicular to said ABS; and

25 the insulation stack having been formed subsequent to said sensor and at least the first pole piece layer having not been subjected to annealing in the presence of a magnetic field directed parallel to the ABS before said heating of the layer of the insulation stack; and

at least one of the first and second shield layers and the first and second pole piece layers comprising NiFeCo-O-N or NiFeCo-N;

30 a housing;

a magnetic disk rotatably supported in the housing;

a support mounted in the housing for supporting the magnetic head with its ABS site facing the magnetic disk so that the magnetic head is in a transducing relationship with the magnetic disk;

spindle motor for rotating the magnetic disk;

5 an actuator means connected to the support for moving the magnetic head to multiple positions with respect to said magnetic disk; and

a processor connected to the magnetic head, to the spindle motor and to the actuator for exchanging signals with the magnetic head, for controlling movement of the magnetic disk and for controlling the position of the magnetic head.

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11. A magnetic disk drive as described in claim 10 wherein the second shield layer and the first pole piece layer are a common layer.

12. A magnetic disk drive as described in claim 10 wherein the second shield  
15 layer and the first pole piece layer are separate layers and are separated by a nonmagnetic insulative isolation layer.

13. A magnetic disk drive as described in claim 10 wherein the second shield layer comprises NiFeCo-N.

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14. A magnetic disk drive as described in claim 10 wherein the second pole piece layer comprises a laminated layer of NiFeCo-O-N films with interlayer films of  $\text{Al}_2\text{O}_3$  or  $\text{SiO}_2$ .

25 15. A magnetic disk drive as described in claim 14 including:  
a seed layer comprising NiFeCo-O-N;  
the second pole piece layer being directly on the seed layer; and  
the seed layer having higher  $\text{O}_2$  and  $\text{N}_2$  contents than the NiFeCo-O-N of the second pole piece layer.

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16. A magnetic disk drive as described in claim 15 including:  
a bottom layer of SiO<sub>2</sub>; and  
the seed layer being located between the bottom layer and the second shield  
layer.

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17. A magnetic disk drive as described in claim 16 wherein the laminated  
layer includes four NiFeCo-O-N films that are each substantially 4500 Å thick.

18. A magnetic disk drive as described in claim 17 wherein the second shield  
10 layer comprises NiFeCo-N.

19. A method of making a magnetic layer with in-plane anisotropy and high  
H<sub>K</sub> after hard axis annealing in the presence of a field perpendicular to the plane  
comprising the steps of:

15 providing a DC magnetron which has a chamber, a target and a substrate;  
the target being NiFeCo;  
providing a first process gas in the chamber which is composed of an inert gas  
and a nitrogen containing gas; and  
sputtering the target to form said magnetic layer composed of NiFeCo-O-N or  
20 NiFeCo-N on the substrate.

20. A method as described in claim 19 wherein no bias is applied to the  
substrate.

25 21. A method as described in claim 19 wherein the first process gas includes  
1.6% to 3.2% N<sub>2</sub>O and each of the NiFeCo-O-N films is about 4,500 Å thick.

22. A method as described in claim 19 wherein the first process gas includes  
1.6% to 3.2% N<sub>2</sub>O and the magnetic layer is a single film 2,500 Å to 6,000 Å thick.

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23. A method as described in claim 19 wherein the first process gas includes 1.0% to 2.0% N<sub>2</sub> and the magnetic layer includes a single film 4,500 Å to 18,000 Å thick.

5           24. A method as described in claim 19 wherein the target is (Ni<sub>0.80+x</sub>Fe<sub>0.20-x</sub>)<sub>1-y</sub>Co<sub>y</sub> where  $-0.05 \leq x \leq 0.05$  and  $0.00 \leq y \leq 0.15$  (wt. fraction).

25. A method as described in claim 19 wherein the first process gas is said inert gas and N<sub>2</sub> and the target is sputtered to form a single film of NiFeCo-N about  
10   1.8 μm thick.

26. A method as described in claim 25 wherein the first process gas includes 1.0% to 2.0% N<sub>2</sub>.

15           27. A method as described in claim 26 wherein during sputtering the first target, a pressure between  $1 \times 10^{-3}$  to  $3 \times 10^{-3}$  is maintained within said chamber and the magnetic film comprises one or more films of NiFeCo-N from 4,500 Å to 18,000 Å thick.

20           28. A method as described in claim 19 including:  
sputter depositing multiple interlayer films of Al<sub>2</sub>O<sub>3</sub> or SiO<sub>2</sub>; and  
the first process gas is said inert gas and N<sub>2</sub>O;  
sputtering the target multiple times to deposit multiple NiFeCo-O-N magnetic  
films;  
25           and alternating the depositions to form the magnetic layer as a lamination of  
magnetic and interlayer films.

29. A method as described in claim 28 including:

hard axis annealing the magnetic layer at about 232° C in the presence of magnetic field perpendicular to a major plane of the magnetic layer for about 400 minutes; and

5 after said hard axis annealing, the magnetic layer having an  $H_K$  from 2.6 Oe to 6.0 Oe and in plane anisotropy.

30. A method as described in claim 28 wherein the first process gas includes 1.6% to 3.2%  $N_2O$  and each of the NiFeCo-O-N films is about 4,500 Å  
10 thick.

31. A method as described in claim 28 wherein no bias is applied to the substrate.

15 32. A method as described in claim 28 wherein before sputtering the target, sputter depositing a seed layer of NiFeCo-O-N with a second process gas that has a higher  $N_2O$  content than the first process gas.

33. A method as described in claim 32 wherein the seed layer is 25 Å to  
20 200 Å thick.

34. A method as described in claim 32 including:

before sputter depositing the seed layer, sputter depositing a bottom layer of  $SiO_2$  so that the seed layer is located between the bottom layer and the magnetic layer.

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35. A method as described in claim 32 wherein the  $N_2O$  content in the second process gas is from 2.4% to 4.0%.

36. A method as described in claim 35 wherein no bias is applied to the  
30 substrate.

37. A method as described in claim 36 including:

before sputter depositing the seed layer, sputter depositing a bottom layer of  $\text{SiO}_2$  so that the seed layer is located between the bottom layer and the magnetic layer.

5        38. A method as described in claim 37 wherein the seed layer is 25 Å to 200 Å thick.

39. A method as described in claim 38 wherein the bottom layer is about 25 Å thick.

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40. A method as described in claim 39 wherein four NiFeCo-O-N magnetic films are deposited with each magnetic film being about 4500 Å thick and each interlayer film being about 25 Å thick.

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